How hard is diffractive Higgs production?

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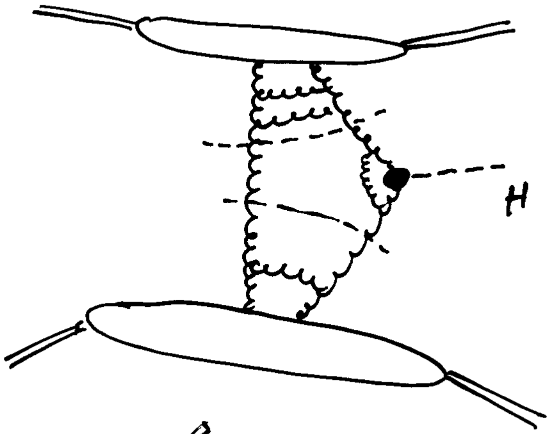
HERA – LHC Workshop

Overview

1. Formalism (KKMR)
2. Uncertainties in the gluon
3. Scale dependence
4. Sensitivity to low momenta
5. Separation of hard and soft
6. Conclusions

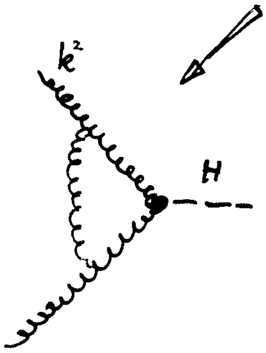
Formalism for elastic H production
(V. Khoze, A. Martin, M. Ryskin, A. Kaidalov)



$\tilde{f}_g$

$A_{hard} \cdot$ (virtual corrections)

$\tilde{f}_g$



at 1 loop one finds

$$-\frac{3}{4\pi}\alpha_s \log^2 \frac{M_H^2}{k^2} + c\alpha_s \log \frac{M_H^2}{k^2}$$

No counterpart from real emissions

Exponentiation of the corrections

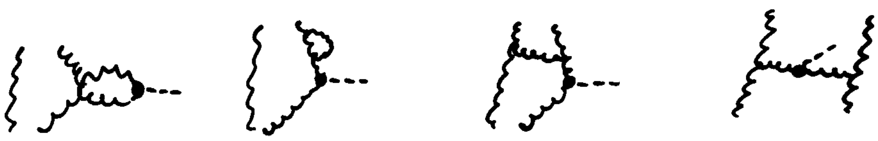
$\Rightarrow$ Sudakov FF

$$T = \exp\left[-\int_{q^2}^{\mu^2} \frac{dk^2}{k^2}\alpha_s(k^2)\int_0^{1-\Delta}\left[zP_{gg}(z) + \sum_q P_{qg}(z)\right]\right]$$

at 2L accuracy Δ - arbitrary

1L accuracy $\Delta = \frac{k}{k + 0.62\, m_H}$

Other diagrams



do not contribute to the Sudakov but enter the K-factor

Formalism (contd)

$$\tilde{f}_g(k, x_1)\; T\; \tilde{f}_g(k, x_2) \;\longrightarrow\; \overbrace{\sqrt{T}\,\tilde{f}_g(k, x_1)}^{f_g(x, k^2, \mu)}\; \sqrt{T}\, f_g(k, x_2)$$

This would spoil $\quad xg(x, Q^2) = \int_0^{Q^2} f_g(x, k^2, Q)\, \frac{dk^2}{k^2}$

so $\quad f_g(x, k^2, \mu) = \frac{\partial}{\partial \log k^2}\left[\sqrt{T(k^2, \mu)}\; xg(x, k^2)\right]$

(Kimber Martin Ryskin)

Large 1-logs from $\frac{\partial \sqrt{T}}{\partial \log k^2}$?

treatment of the partons that are obtained in the unintegrated form? (LDC, KMS, CCFM)

Off-diagonal effects in $x \rightarrow R_g$ [Shuvaev]

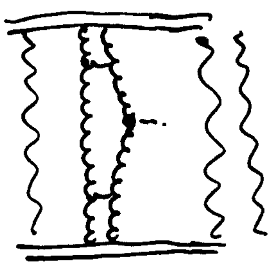
Hard part : $\quad M \sim R_g^2 \int \frac{dk^2}{k^4}\, f_g(x_1, k^2, \mu)\, f_g(x_2, k^2, \mu)$

Soft rescatterings $\longrightarrow$ soft gap survival factor

Described by 2-channel eikonal model (KMR)

Important assumption:

Hard part of the amplitude is independent of the soft processes



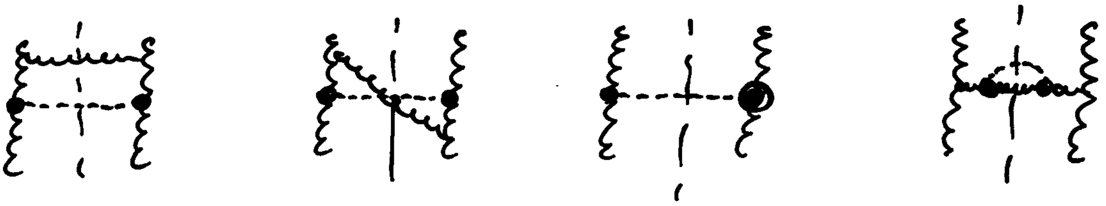
$$\Rightarrow \quad \sigma_{\text{elastic}} = \left[\int d^2b\; e^{-\Omega(b)/2} \sqrt{\left.\frac{d\sigma(b)}{d^2b}\right|_{\text{hard}}}\;\right]^2$$

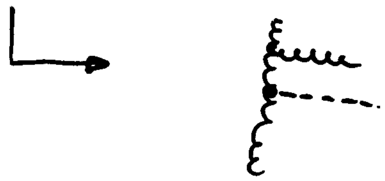
Remark on the K-factor

The standard K-factor

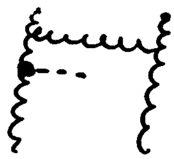
$$\left(1+\frac{\alpha_s(M_H^2)}{\pi}\left[\pi^2+\frac{11}{2}\right]\right)\approx 1.5$$

is the log-free part of radiative corrections in the inclusive case $gg\to H$





hard emissions contribute having no counterpart in the elastic case as the screening gluon cannot absorb hard radiation



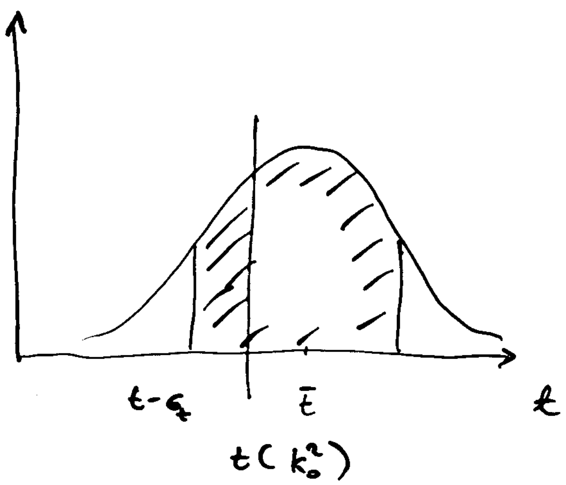
Contribution from low k_T

At DLA : $I = \int dt \exp\left[(1-2\gamma)t - \frac{3\alpha_s}{4\pi} t^2\right]$

$$\bar{t} = \overline{\log \frac{\mu^2}{k^2}} = \frac{2\pi}{3\alpha_s}(1-2\gamma) \rightarrow \quad k^2 \sim 3-4 \text{ GeV}^2$$

But: $\sigma_t = \sqrt{\frac{2\pi}{3\alpha_s}} \sim 2.5$

and $\bar{t} - \bar{\sigma}_t \longrightarrow \quad k^2 \sim 0.3 - 0.4 \text{ GeV}^2$



- We need a good controll of the gluon at $Q^2 \sim 1 \text{ GeV}^2$ and below
- Additional contributions from $q^2 \frac{\partial T(q^2,\mu)}{\partial q^2}$ at low q
- Perturbative partons do not go below $Q^2 \sim 1 \text{ GeV}^2$ and even at larger Q^2 may be contaminated by screening corrections
- Extrapolation which will be used

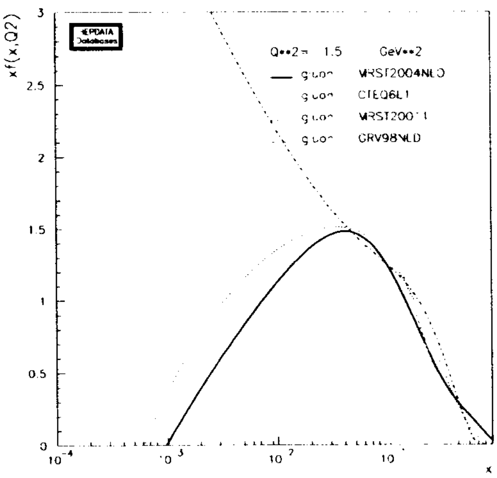
$$f_g(x, k^2 < k_0^2, \mu) = xg(x, k_0^2)\frac{\partial \sqrt{T}}{\partial \log k^2} + \frac{\partial(xg)}{\partial \log k^2}\Big|_{k_0^2} \sqrt{T}$$

Uncertainties of gluon at low Q^2

$f_g(x, k_t^2, \mu)$ at low $k_t^2 \longrightarrow$

$xg(x, Q^2)$ at low Q^2

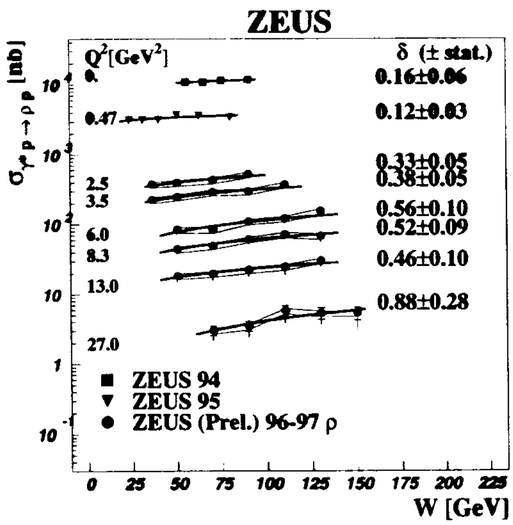
central Higgs production at LHC $\longrightarrow x \sim 0.01$



elastic VM production $\sigma \sim [xg(x, Q^2)]^2$

gluon should not vanish at $x \longrightarrow 0$ (modulo NL)

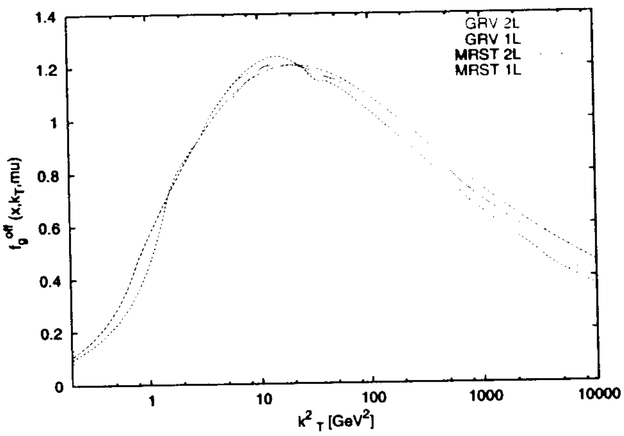
saturation effects diminish gluon



Unintegrated gluons

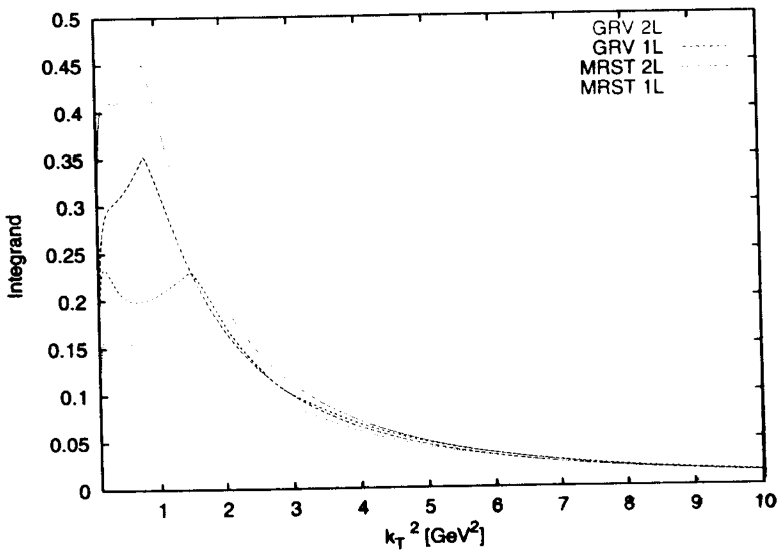
KKMR prescritption for unitegrated gluon ⟶

Off shell, double scale gluons from MRST2001 and GRV NLO



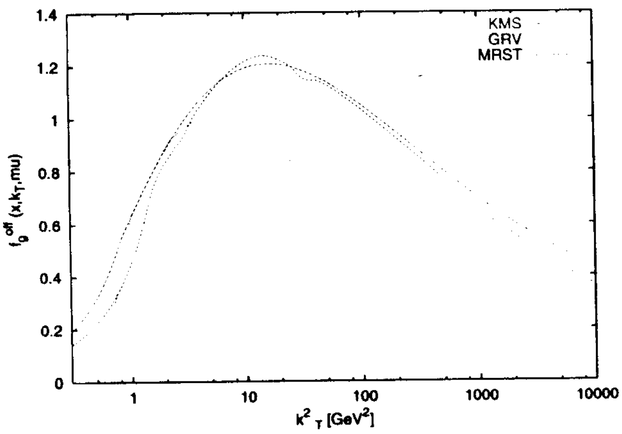
Relevant is integrand $I(k^2)$ in amplitude $pp \to ppH$

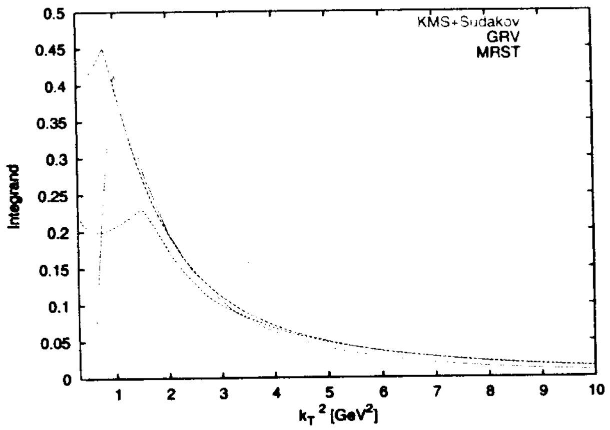
$$A \sim \int dk^2 I(k^2), \qquad I(k^2) = [f(x_1, k^2, \mu)\, f(x_2, k^2, \mu)]/k^4]$$



Unintegrated gluons – KMS

$$f_g(x_1, k^2, \mu) = \sqrt{T(k^2, \mu)}\, f_g(x_1, k^2)$$

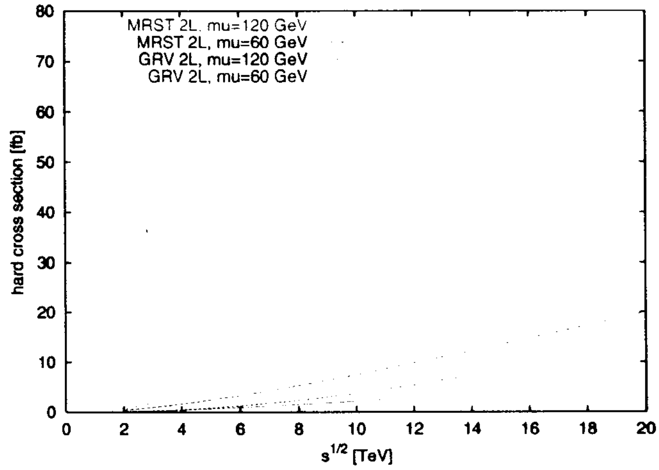




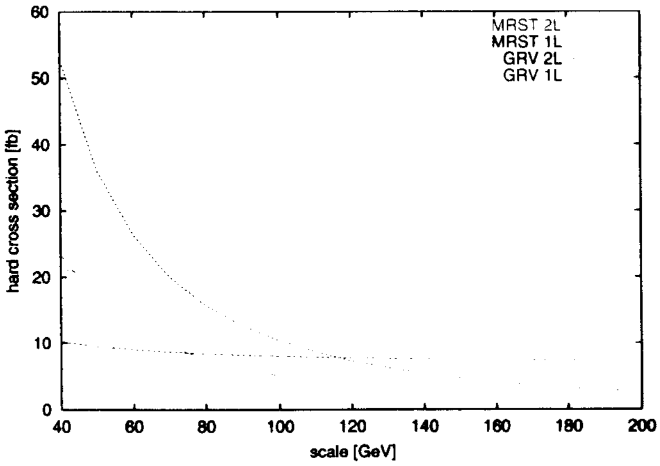
- inclusion of Sudakov FF $\longrightarrow$ need to refit KMS
- similarities of different f_g down to $k^2 = 1.5$ GeV^2
- uncertainties of low k_T extrapolations
- relatively low gluon momenta dominate

Scale sensitivity at single and double log accuracy

Total cross section at double log accuracy is very sensitive to te choice of scale ($\mu = 60, 120 GeV$)



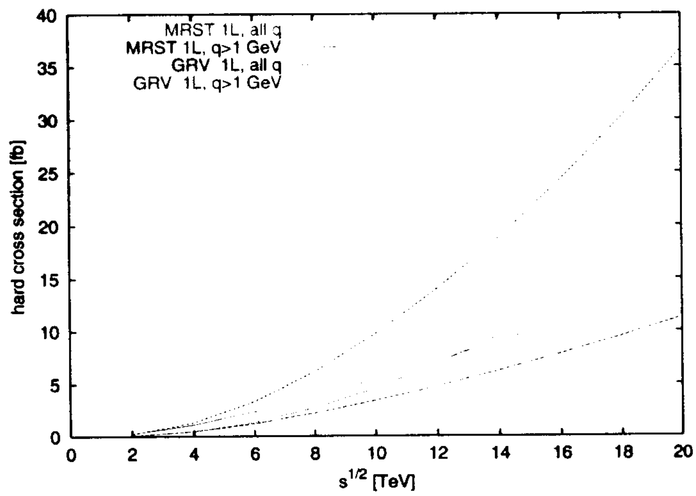
Sensitivity to factorisation scale μ at ~~double and~~ single log accuracy is substantially **reduced**



Sensitivity to low k_T

MRST lead to results stable in the IR but GRV gluon gives larger cross section with larger contribution from low momenta

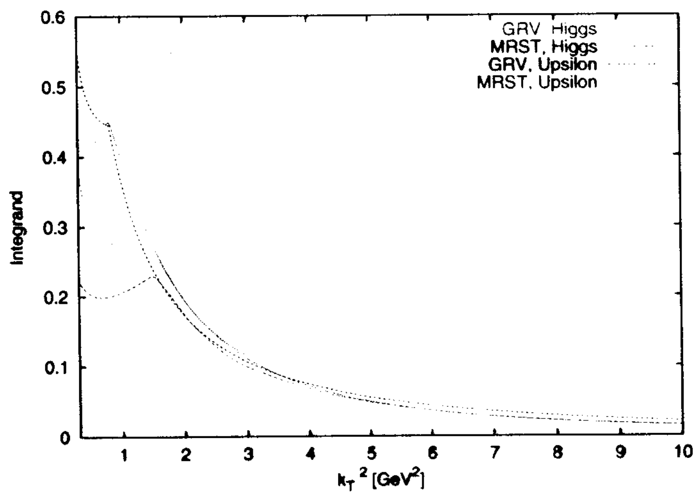
need to controll low k_t region better!



"Comparative hardness": Υ photoproduction in at HERA vs elastic Higgs production at LHC

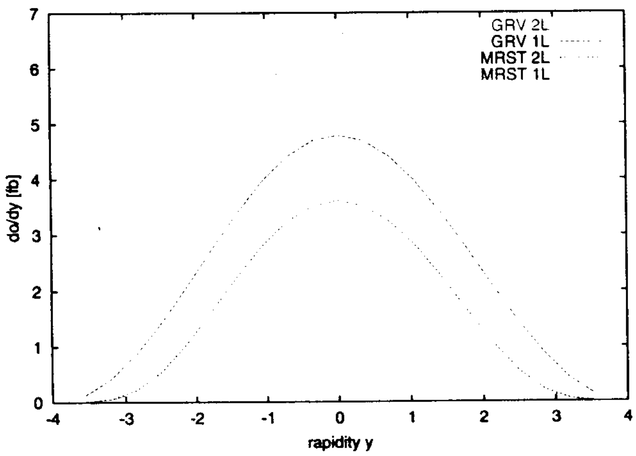
$$\int \frac{dk^2}{k^4} f_g(x, k_t^2, m_b) \frac{k^2}{k^2 + m_b^2}$$

$\longrightarrow$ similar region of k_t is probed

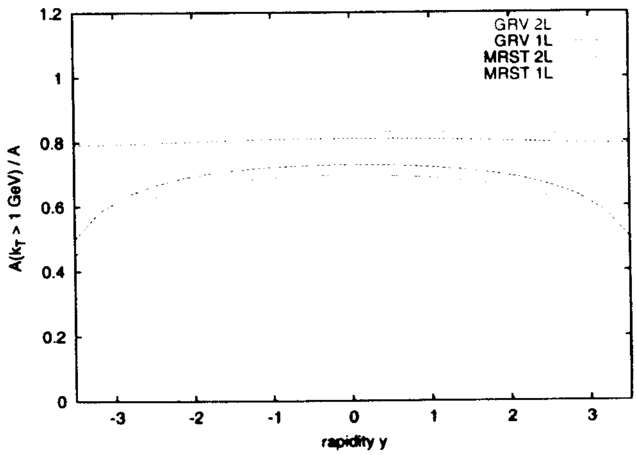


Rapidity dependence of $d\sigma/dy$ and 'hardness'

Shape of $d\sigma/dy(pp \to ppH)$ is not sensitive to the details



Relative contribution of the amplitude from the hard region weakly depends on rapidity



Rescattering of the hard ladder:

Typical momenta in the ladder $\sim k = 2$ GeV

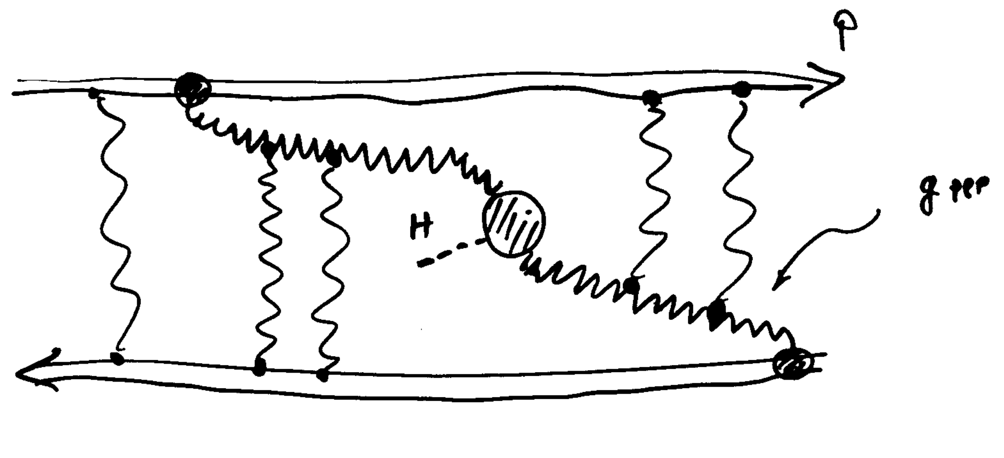
(Collision energy)^2 between the ladder and the proton $S_{\mathbb{P}P} = x_H S_{pp} \approx 2\cdot 10^6$ GeV^2 at LHC

Saturation scale from HERA data $Q_s^2 \sim \left(\frac{x}{x_0}\right)^{-0.3} Q_0^2$

with $x_0 \sim 3\cdot 10^{-4}$, $Q_0 = 1$ GeV $\Rightarrow$

$p\mathbb{P}$ scattering in H production is characterised by saturation scale $Q_s^2 \sim 6$ GeV^2

$\Rightarrow$ soft rescatterings of the hard ladder are important



Consistent with Bartels, Ryskin and Vacca estimate that triple pomeron contributions for momenta $\ell^2 \sim 2$ GeV^2 are relevant if $Y > 4-5$

Here $\mathbb{P}-p$ rapidity is much larger: $Y > 12$

IF THERE ARE NO IMPORTANT CANCELLATIONS DUE TO INTERFERENCE BETWEEN p AND $\mathbb{P}$ SCATTERING THAN SCREENING OF THE HARD LADDER MAY BE A SOURCE OF LARGE CORRECTIONS

Summary

1. We find that typical k_T^2 of gluons in $pp \longrightarrow ppH$ is $\sim 1 - 2$ GeV^2
2. Unitegrated gluon is poorly constrained in region of $k_T < 1$ GeV^2 which may lead to significant uncertainty in the production cross section
3. The k_t profile of the amplitude integrand is similar for elastic production of Υ at HERA and Higgs at LHC
4. It is essential to go beyond double log resummation in Sudakov form factor when defining the unintegrated gluon
5. Indications that rescatterings of the hard ladders may take place.